Metopia: Experiencing Complex Environmental Data Through Sound

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ABSTRACT

This extended abstract describes Metopia, a research project in the early stages of progress, a wireless sensor network for urban spaces, to aquire a complex set of data from the environment for the purpose of making a sound composition. The programming language Pure Data is used to create a sound composition from the aquired data. This research project is using a real-world problem such as air-pollution as a way to explore a responsive environment, to communicate the state of the toxic level into an immediate auditory response. Atmospheric pollutants is a major health issue and Metopia is one way of examining this problem through aesthetic and conceptual choices and at the same time making sense of complex data through generative principles and through algorithms. The composition is using Pure Data on embedded Raspberry Pi 2 equipped with ARM processors for real-time processing, coupled with an array of sensors using Arduino for data acquisition.

1. INTRODUCTION

"Metopia" is a research project in an early stage, where a wireless sensor network acquires atmospheric data for an immediate auditory response, to experience pollution in novel ways, in addition to visualizations that already exists as Apps and on websites. Metopia is using Pure Data [1] on embedded ARM processors, Raspberry Pi 2 [2]. Metopia is using a real-world problem as part of the design methodology. Air-pollution is a major health concern. The World Health Organization (WHO) attributed 3.7 million deaths due to ambient pollution in 2012 [3]. This problem of air-pollution is addressed to answer relevant questions, such as, how complex data can be managed in a sound composition and how complex data can be experienced though auditory means.

2. BACKGROUND

The focus of this research project is how to implement a system to manage large amounts of data for an auditory experience. In the era of Internet of Things (Iot) and Big Data, data visualization is the common way to represent data. In this research project, large amount of data is examined with auditory means, using generative principles, either through hard coding the sensor data, or though machine learning [5],[7] as two different approaches in managing large data streams. This examination is in relation to how much sound processing the the designed system, consisting of Pure Data running on Raspberry Pi's in conjunction with data acquisition on Arduinos, is able to handle.

3. PREVIOUS WORKS

There are numerous works related to this project that could be part of this survey. However, a few works are interesting for the reason that they can be conceptualized as a system design for a music composition. One work in networked music using complex data and networks that is interesting to mention in this context, is Max Neuhaus' work "Auracle" for live interaction using voice over the Internet [6]. Another work related to this project is based on sensor technologies and machine learning, is the adaptive neural network for "Kroonde" and "Toaster" created at La Kitchen in Paris by Cont, Coduy and Henry, where Pure Data was used with the Reduced-Memory-Levenberque- Marquardt algorithm for sensor mapping [7]. The idea of complexity and music composition has been explored by many composers, and to mention one composer, Iannis Xenakis piece "Bohor" (1962), where he expresses the complexity of distributed sound as sound textures [8].

Previous works using embedded audio, made by the author, since processing capabilities is essential to this project running Pure Data on GNU/Linux OS, is "Noise Apparatus" in 2006-2007 [9], interactive handheld audio using iPAQ on HP 5550, an Atmel XScale processor running 400MHz, where Pure Data was used for sound synthesis [10]. Another related project was "Ghost Scraper" 2008-2009 [11], using Pure Data for sound processing on Gumstix embedded processors [12].

4. THE SYSTEM DESIGN OF METOPIA

The system design of Metopia is presented here briefly, to provide a general overview. Metopia's system design, a mesh network, is implemented using Rasperry Pi 2, chosen for several reasons is described below.

- It can run a GNU/Linux, Debian operating system.
- The relative small size to implement a portable system.
- The processing power on the ARM Quad-core Cortex-A7 processor, clocked at 900Hz is acceptable [13].
- The low cost of the device.
- The large user and educational community. Odroid-C or Beaglebone Black could both be used for this project as well, but Raspberry Pi has the larger user community.

The Raspberry Pi 2 is running the GNU/Linux/Debian OS, Pure Data for the sound composition, chosen because of its portability for embedded systems. An Arduino is used for data acquisition of an array of environmental sensors and

location data from GPS. Each node in the network are identical with sensors and location data, so the data can be accessible to the user in an urban space setting. The system is created using a mesh network, using ZigBee RF modules Pro ZB [13] and its protocol to be able to read data from each node, including one node connected to the Internet via a USB modem [14], all powered using portable batteries. The end point, where the user interact with the system, is location specific.

5. COMPLEX DATA IN COMPOSING MUSIC

Managing complex data sets is a challenge for a music composition for several reasons, the limited processing power for a portable system, the management and groupings of data for the composition, and at the same time designing for an auditory experience of the responsive environment. In order to implement a musical composition and test the aesthetics and processing with an interactive wireless sensor system, two different software implementations are created.

- One hardcoded software implementation in Pure Data, using generative principles.
- One version using machine learning and Pure Data, to map sensor data to audio processing.

5.1. Hardcoding Using Generative Principles

The hardcoded music composition, is using generative principles in mapping the sensor data in Pure Data. In this composition, musical elements such as textures, densities, color, and dynamics are used, and not meter, chords, rhythm, and harmonies. The generative mapping is made based on variations in daylight and temperature as a way to modulate the textures. In this version, the data streams are hardcoded in Pure Data, using sound processing and filters. This is a very precise way of setting up the sonic output, but the downside is that it is not very flexible if there is a change in the system.

5.2. Machine Learning

Machine learning is the second approach to map the sensor data to the sound processing in Pure Data. One challenge is the amount of data being processed on each node and training this data in supervised machine learning in relation to available processing power. The type of algorithms needed for this kind of musical composition are smoothing and filtering algorithms for noise in the data streams, and classifiers, to apply a generative principle, to be able to control a modulation based on daylight as in the hardcoded version. Cont et. al. suggest the Reduced-Memory-Levenberque-Marquardt algorithm [7]. Fiebrink in the "Wekinator" project is using a range of algorithms, such as Adaboost, Hidden Markov Model for smoothing and filtering along with lbk and J48 classifiers [5]. The gain in the approach using machine learning, would be a flexible system for mapping and handling specific data streams for sound processing [5]. Wekinator will be tried as part of the tests [5] for the future developments.

6. FIRST TESTS

This project is a work in progress, and first tests has been made using Pure Data processing on the Raspberry Pi 2 [2]. "Wekinator" [5] will be used as part of upcoming tests to test the processing power in the supervised training, before further tests are being made in implementing machine learning.

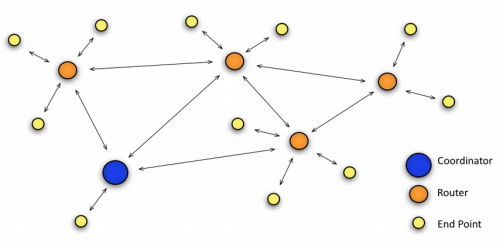

Figure 1: The wireless sensor network is constructed in a mesh topology.

7. DISCUSSION

After designing the first prototype and making the first tests, development work of the sound composition will be made to meet the aesthetic challenges of the composition and at the same time consider the capabilities of the processing power and energy consumption of the system. Even if the project is in an early stage, there is a potential for future work in distributed sonification for urban space.

8. REFERENCES

[1] Pure Data. [online] <http://puredata.info>
[2] Raspberry Pi 2. [online] <https://www.raspberrypi.org/products/raspberry-pi-2-model-b/>
[3] World health organization (WHO). [online] <http://www.who.int/gho/phe/en/>
[4] City Air App, [online] <https://play.google.com/store/apps/details?id=uk.ac.kcl.erg.cityair>
[5] Wekinator, [online] <http://wekinator.cs.princeton.edu/>
[6] M. Neuhaus, "Auracle" [online] <http://www.auracle.org/>
[7] Cont, A.,Coduys, T., Henry, C. "Real-time Gesture Mapping in Pd environment using Neural Networks" in *Proceedings NIME 04*, Hamamatsu, Japan
[8] Chadabe, Joel. The evolution of Xenakis' models of complexity in relation to electronic technology. *Past, Present and Future Conference*, Polytechnique Institute of New York University [online] <https://www.youtube.com/watch?v=pxWbvCvrrlk>
[9] iPAQ HP5550, Atmel XScale, [online], <http://moolab.net/projects/noise.html>
[10] *Make Art Festival*: Free Software and Digital Art, Poitiers, France [online] <http://makeart.goto10.org/2007/?lang=en>
[11] Sjuve, E. Ghost Scraper, [online] <http://moolab.net/projects/ghostscraper.html>
[12] Gumstix Verdex Pro Board, [online] <https://store.gumstix.com/index.php/products/209/>
[13] ZigBee Pro ZB [online] <http://www.digi.com/products/wireless-wired-embedded-solutions/zigbee-rf-modules/zigbee-mesh-module/xbee-zb-module>
[14] Huawei 220 USB modem. [online] <http://www.huaweie220.com/>